

**Review of same-side tagging  
for  $B_s \rightarrow \mu\phi\pi$ ,  $B_s \rightarrow J/\psi\phi$   
and  $B \rightarrow J/\psi K$  decays**

A. Rakitin

Lancaster University

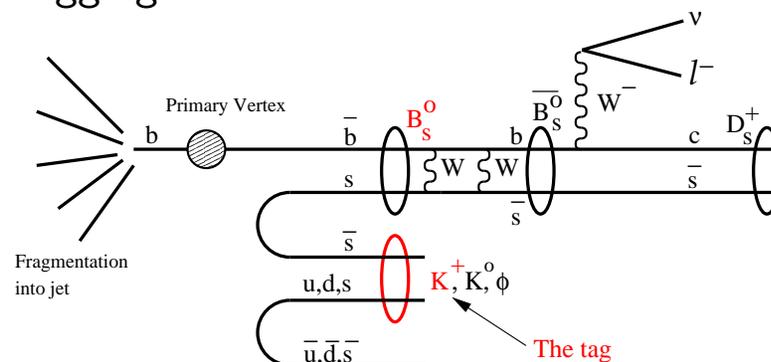
November 1, 2007

*B* Mixing and Lifetime



# Short introduction

- When  $\bar{b}$ -quark picks  $s$ -quark (forming  $B_s$  meson) it leaves  $\bar{s}$  to form accompanying  $K^+$
- Similarly,  $b$ -quark forms  $\bar{B}_s$  meson and accompanying  $K^- \implies$  can use this kaon for same-side  $b$ -quark flavor tagging



- To quantify the tagging performance we calculate:
  - number of events with right-sign  $B_s - K^+$  and  $\bar{B}_s - K^-$  correlations,  $N_{RS}$
  - numbers of events with wrong-sign  $B_s - K^-$  and  $\bar{B}_s - K^+$  correlations,  $N_{WS}$
  - number of events with no accompanying kaon found,  $N_{NT}$
  - tagging efficiency  $\epsilon = \frac{N_{RS} + N_{WS}}{N_{RS} + N_{WS} + N_{NT}}$ , dilution  $D = \frac{N_{RS} - N_{WS}}{N_{RS} + N_{WS}}$  and tagging power  $\epsilon D^2$
- $B_s$  production flavor is obtained from MC truth information  $\implies$  analysis can only be done on Monte Carlo
- SST technique can be verified on self-tagging  $B \rightarrow J/\psi K$  sample



# Available Monte Carlo samples:

- p17  $B_s/B_d/B_u/\Lambda_B \rightarrow \mu\phi\pi$  (200K events)
- p17  $B_s \rightarrow \mu\phi\pi$  (200K events)
- p17 “unbiased”  $B_s \rightarrow \mu\phi\pi$  (250K events)
  - “Unbiased” means that  $\mu$  doesn’t have to come from  $B_s$
- p20  $B_s \rightarrow \mu\phi\pi$  (450K events)
- p17(?)  $B_s \rightarrow J/\psi\phi$  (38K events)
- p17 MC  $B^+ \rightarrow J/\psi K^+$  (170K events)
- p17 MC  $B^- \rightarrow J/\psi K^-$  (210K events)



# List of used same-side taggers:

We are using the following SSTs (one-track and many-track taggers):

➔ Min.  $p_t^{\text{rel}}$

➔ Max.  $p_L^{\text{rel}}$

➔ Max.  $p_t$

➔ Min.  $|\Delta\vec{P}| \equiv |\vec{p}(B_s) - \vec{p}(K)|$

➔ **Best: Min.  $\Delta R$**

➔ Max.  $\cos \alpha$

➔ Min.  $\cos \theta^*$

➔ Max.  $\cos \theta^*$

➔ Min.  $m(B_s K)$

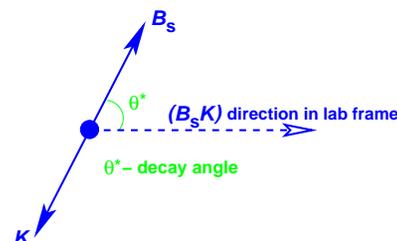
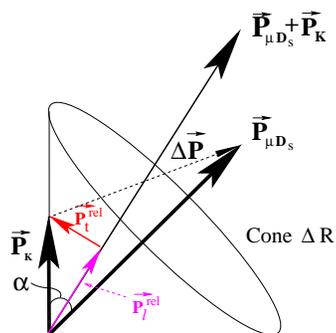
➔ Random track

➔  $Q_{jet}(p_t, \kappa) = \frac{\sum q \cdot p_t^\kappa}{\sum p_t^\kappa}$

➔  $Q_{jet}(p_t^{\text{rel}}, \kappa) = \frac{\sum q \cdot (p_t^{\text{rel}})^\kappa}{\sum (p_t^{\text{rel}})^\kappa}$

➔  $Q_{jet}(p_L^{\text{rel}}, \kappa) = \frac{\sum q \cdot (p_L^{\text{rel}})^\kappa}{\sum (p_L^{\text{rel}})^\kappa}$

➔ **Best:  $Q_{jet}(p_t, \kappa = 0.6)$**

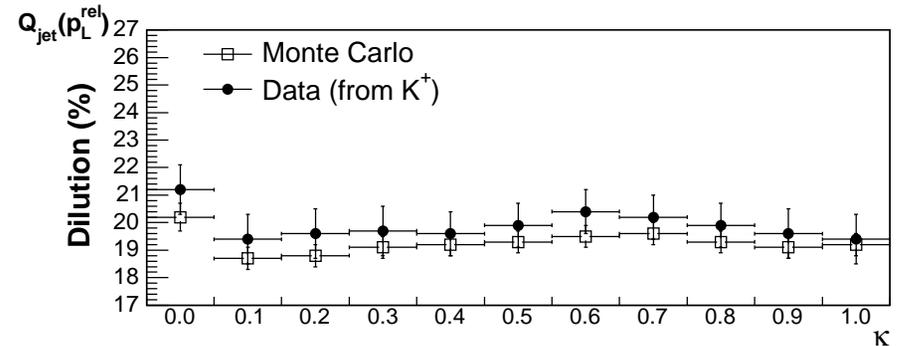
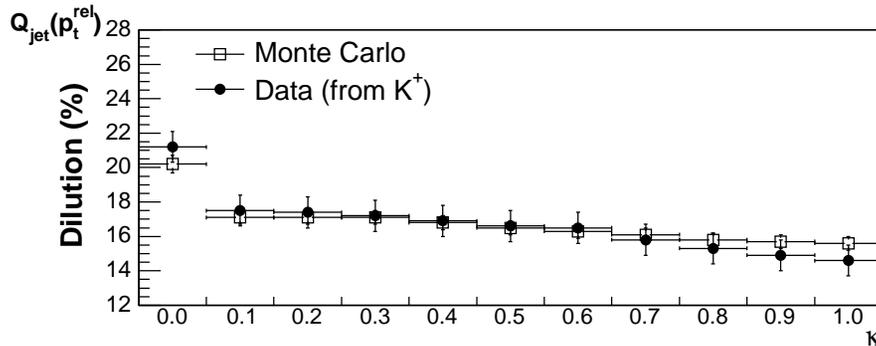
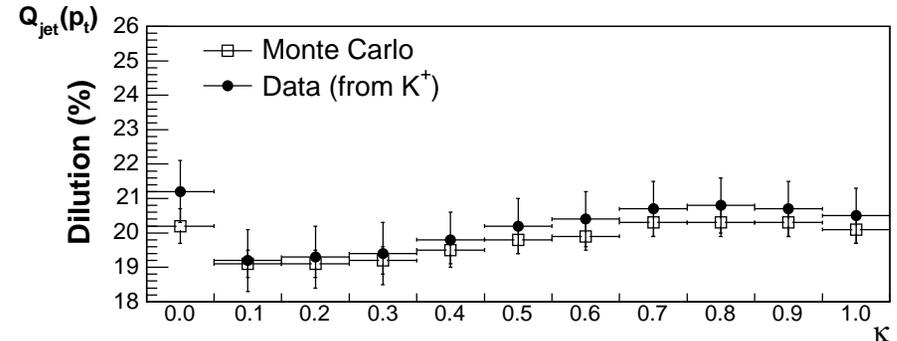
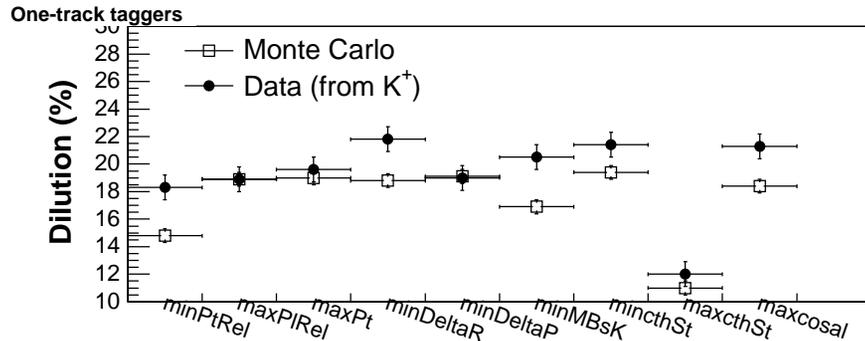


- One-track:  $p_t^{\text{rel}}$  and  $p_L^{\text{rel}}$  are  $\perp$  and  $\parallel$  components of SST candidate's momentum  $\vec{p}(K)$  w.r.t  $\vec{p}(B_s K)$
- $\Delta R \equiv \sqrt{\Delta\phi^2 + \Delta\eta^2}$  and angle  $\alpha$  are taken between  $\vec{p}(B_s)$  and  $\vec{p}(K)$
- $\theta^*$  - decay angle of  $B_s K$ -system, *i.e.* angle between directions of  $\vec{p}(B_s K)$  and  $\vec{p}(B_s)$  in reference frame of  $B_s K$  system
- $\kappa = 0.0, 0.1, 0.2, \dots 1.0$
- $Q_{jet}$ :  $p_t^{\text{rel}}$  and  $p_L^{\text{rel}}$  are  $\perp$  and  $\parallel$  components of SST candidate's momentum  $\vec{p}(K)$  w.r.t  $\vec{p}(B_s)$



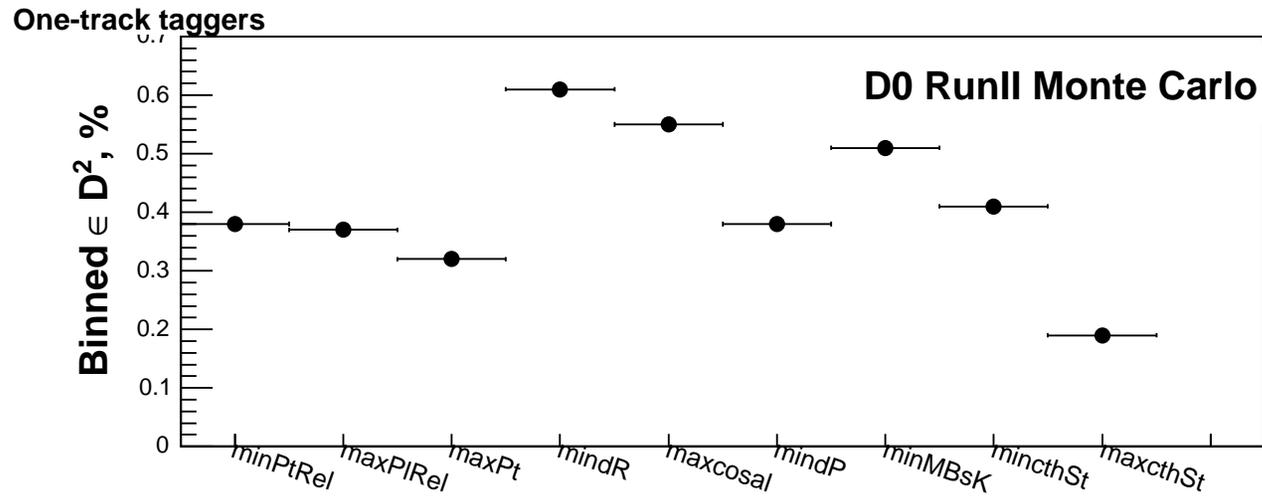
# Can we trust Monte Carlo?

Good data - MC match for dilutions for different taggers for  $B \rightarrow J/\psi K$  decay:



Two more conclusions:

- “Min.  $\Delta R$ ” is the best one-track tagger
- All many-track taggers have approximately the same dilution - let's choose “ $Q_{jet}(p_t, \kappa = 0.6)$ ” for consistency with OST



Another comparison between different taggers for p17 “unbiased”  $B_s \rightarrow \mu\phi\pi$  MC confirms that “Min.  $\Delta R$ ” is the best one-track tagger

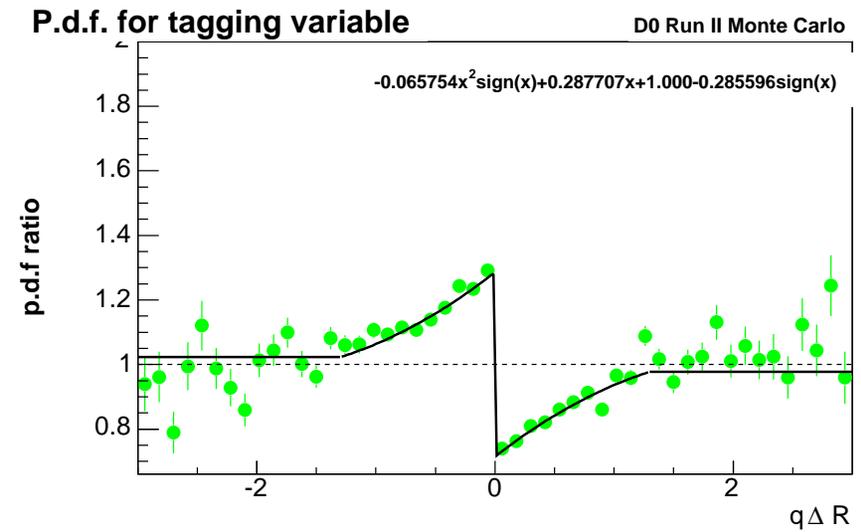
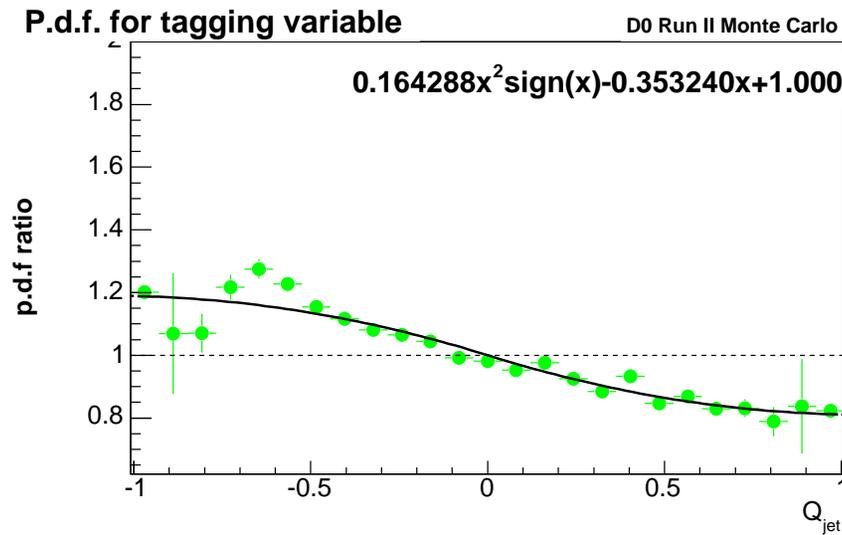
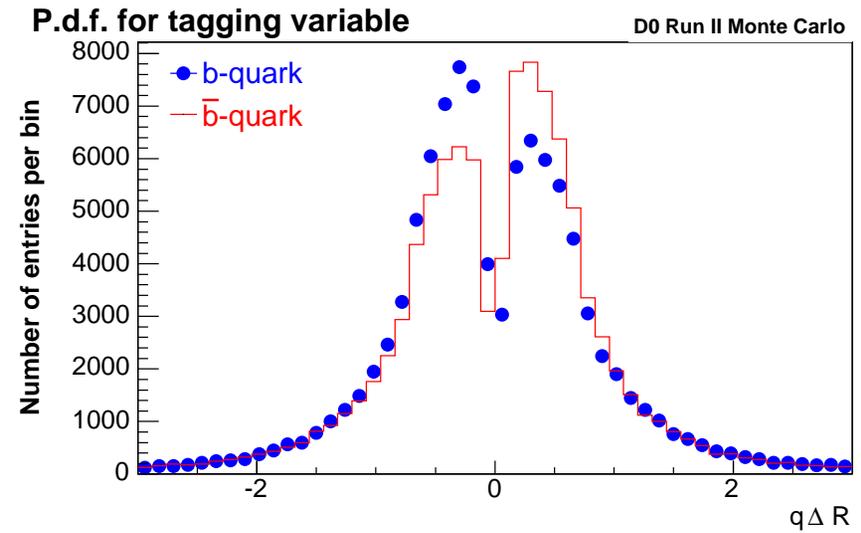
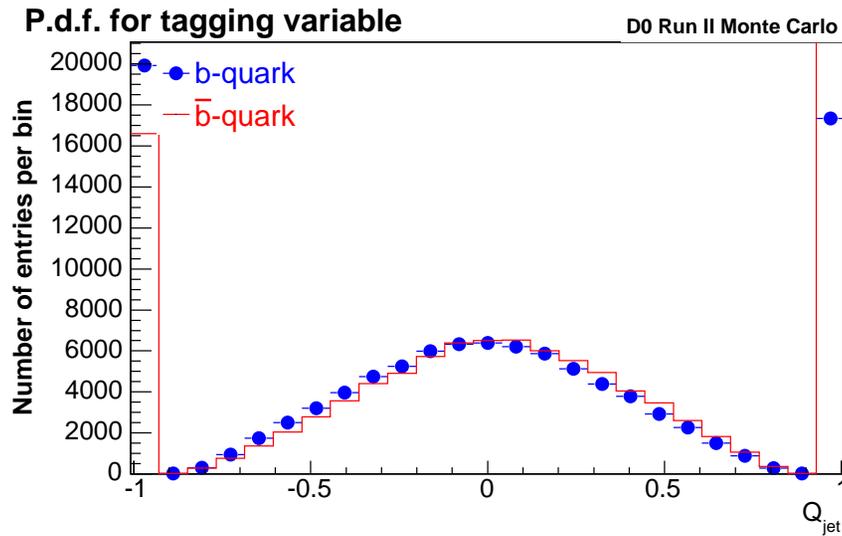


# Combination of both SST algorithms

- The combination algorithm is well-known
- Implemented in class TagCombinedSame
- The p.d.f.s for this algorithm are taken from  $B_s$  Monte Carlo
- To avoid skews from  $B_s$  selection:
  - ☞ Do not use reconstructed  $B_s$ 's
  - ☞ Instead, find  $B_s$  as an MC particle with  $fabs(PDGid) == 531$
  - ☞ Check that it's parent has  $fabs(PDGid)! = 531$
  - ☞ Exclude all  $B_s$ 's children
  - ☞ Pick same-side tag kaon in the cone  $\cos \alpha < 0.8$  around  $\vec{p}(B_s)$ 
    - Probably, should have been using  $\vec{p}(\ell + D_s)$  but it's not worth re-doing now
  - ☞ Fill histograms for tagging variable ( $q \cdot \Delta R$  or  $Q_{jet}$ ) for Right-Sign ( $B_s - K^+$ ,  $\bar{B}_s - K^-$ ) and Wrong-Sign ( $\bar{B}_s - K^+$ ,  $B_s - K^-$ ) correlations
- Fit the histogram ratios, obtained variables  $y_{\Delta R}(q \cdot \Delta R) = f^b(q \cdot \Delta R)/f^{\bar{b}}(q \cdot \Delta R)$ ,  $y_{Q_{jet}}(Q_{jet}) = f^b(Q_{jet})/f^{\bar{b}}(Q_{jet})$  and  $d = \frac{1 - y_{\Delta R} \cdot y_{Q_{jet}}}{1 + y_{\Delta R} \cdot y_{Q_{jet}}}$  for each event
- Finally, obtained dilution  $D$ , tagging efficiency  $\epsilon$  and tagging power  $\epsilon D^2$ : as single values and as functions of  $d$



# P.d.f.s





# $\epsilon D^2$ for combined SST

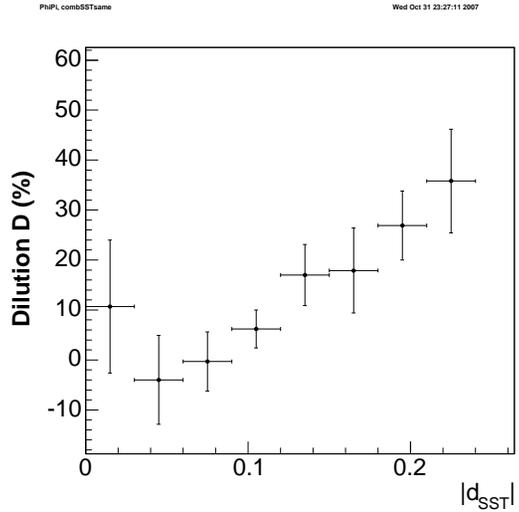
MC	Tagger	$\epsilon$ , %	$D$ , %	Unbinned $\epsilon D^2$ , %	Binned $\epsilon D^2$ , %
p17 $\mu\phi\pi$ "unbiased"	"Min. $\Delta R$ "	$78.0 \pm 2.0$	$10.8 \pm 2.4$	$0.91 \pm 0.41$	$1.12 \pm 0.46$
	" $Q_{jet}(p_t, 0.6)$ "	$89.3 \pm 2.3$	$9.4 \pm 2.3$	$0.79 \pm 0.39$	$1.58 \pm 0.55$
	"Comb. SST"	$89.5 \pm 2.3$	$10.6 \pm 2.3$	$1.00 \pm 0.44$	$1.96 \pm 0.60$
p20 $\mu\phi\pi$	"Min. $\Delta R$ "	$68.9 \pm 0.4$	$14.5 \pm 0.5$	$1.56 \pm 0.10$	$1.70 \pm 0.12$
	" $Q_{jet}(p_t, 0.6)$ "	$85.6 \pm 0.5$	$13.9 \pm 0.5$	$1.69 \pm 0.11$	$2.17 \pm 0.14$
	"Comb. SST"	$83.8 \pm 0.5$	$14.3 \pm 0.5$	$1.78 \pm 0.12$	$2.46 \pm 0.15$
p17 $J/\psi\phi$	"Min. $\Delta R$ "	$68.5 \pm 1.2$	$14.6 \pm 1.6$	$1.46 \pm 0.32$	$1.82 \pm 0.36$
	" $Q_{jet}(p_t, 0.6)$ "	-	-	-	-
	"Comb. SST"	$82.7 \pm 1.3$	$13.0 \pm 1.5$	$1.41 \pm 0.31$	$2.36 \pm 0.40$
p17 $J/\psi K$	"Min. $\Delta R$ "	$76.0 \pm 0.4$	$19.5 \pm 0.5$	$2.90 \pm 0.15$	$3.15 \pm 0.15$
	" $Q_{jet}(p_t, 0.6)$ "	$89.2 \pm 0.5$	$19.7 \pm 0.5$	$3.48 \pm 0.16$	$4.22 \pm 0.18$
	"Comb. SST"	$87.9 \pm 0.5$	$18.2 \pm 0.5$	$2.93 \pm 0.15$	$4.47 \pm 0.18$

We see some improvement in  $\epsilon D^2$  due to tagger combination

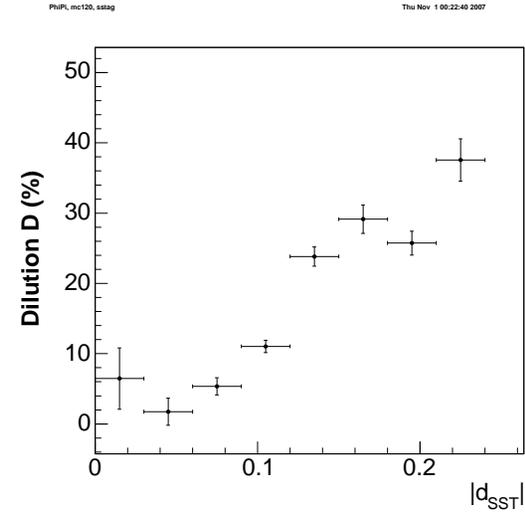


# Combined SST

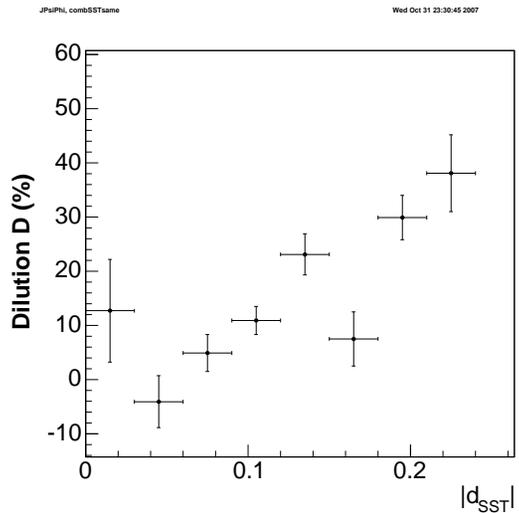
p17 “unbiased”  $B_s \rightarrow \mu\phi\pi$  MC



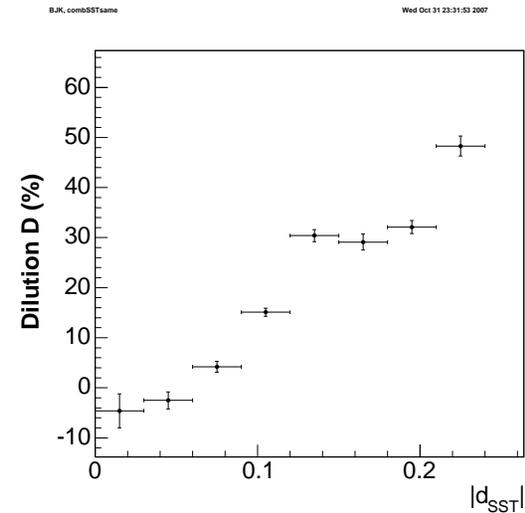
p20  $B_s \rightarrow \mu\phi\pi$  MC



p17  $B_s \rightarrow J/\psi\phi$  MC



p17  $B \rightarrow J/\psi K$  MC





# Combination SST+OST

- Used the same combination algorithm to combine three taggers: SST, OST from D0 Note 4991 and EvtCh (sum of charges of all tracks outside cone  $\cos \alpha > 0.8$ )
- Implemented in class TagCombinedAll
- Notice that  $y_{SST} = f^b / f^{\bar{b}}$  and  $y_{OST} = f^{\bar{b}} / f^b$ 
  - $\implies y_{comb} = y_{OST} / y_{SST} \neq y_{OST} \cdot y_{SST}$
  - ☞ Used  $y_{comb} = y_{OST} / y_{SST}$  if OST is present
  - ☞ Used  $y_{comb} = y_{EvtCh} / y_{SST}$  if OST is not present
- Obtained  $d_{comb} = \frac{1 - y_{comb}}{1 + y_{comb}}$
- Again, obtained dilution  $D$ , tagging efficiency  $\epsilon$  and tagging power  $\epsilon D^2$ : as single values and as functions of  $d_{comb}$



# $\epsilon D^2$ for combined SST+OST+EvtCh



MC	Tagger	$\epsilon, \%$	$D, \%$	Unbinned $\epsilon D^2, \%$	Binned $\epsilon D^2, \%$
	"Comb. OST" (from data)	19.95±0.21	44.3±2.2	2.19±0.22	2.48±0.21
p17 $\mu\phi\pi$ "unbiased"	"Comb. SST"	89.5 ± 2.3	10.6 ± 2.3	1.00 ± 0.44	1.96 ± 0.60
	"Event Charge"	100.0 ± 2.6	10.2 ± 2.2	1.04 ± 0.45	1.53 ± 0.54
	"All"	99.9 ± 2.5	17.1 ± 2.2	2.93 ± 0.74	4.49 ± 0.88
p20 $\mu\phi\pi$	"Comb. SST"	83.8 ± 0.5	14.3 ± 0.5	1.78 ± 0.12	2.46 ± 0.15
	"Event Charge"	99.4 ± 0.6	-7.0 ± 0.5	0.50 ± 0.08	0.71 ± 0.09
	"All"	99.2 ± 0.6	14.0 ± 0.5	1.94 ± 0.13	3.64 ± 0.18
p17 $J/\psi\phi$	"Comb. SST"	82.7 ± 1.3	13.0 ± 1.5	1.41 ± 0.31	2.36 ± 0.40
	"Event Charge"	96.9 ± 1.5	11.2 ± 1.4	1.22 ± 0.29	2.05 ± 0.38
	"All"	97.0 ± 1.5	17.7 ± 1.3	3.03 ± 0.46	4.68 ± 0.54
p17 $J/\psi K$	"Comb. SST"	87.9 ± 0.5	18.2 ± 0.5	2.93 ± 0.15	4.47 ± 0.18
	"Event Charge"	99.9 ± 0.5	10.2 ± 0.4	1.03 ± 0.09	1.32 ± 0.10
	"All"	100.0 ± 0.5	18.3 ± 0.4	3.33 ± 0.16	5.09 ± 0.19

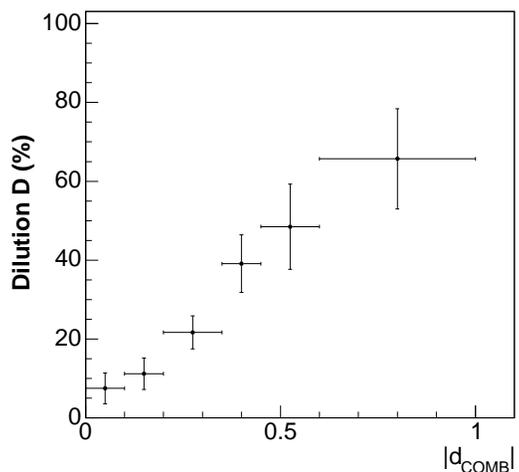


# Combination SST+OST+EvtCh

p17  $B_s \rightarrow \mu\phi\pi$  MC

PHPL.combSSTall

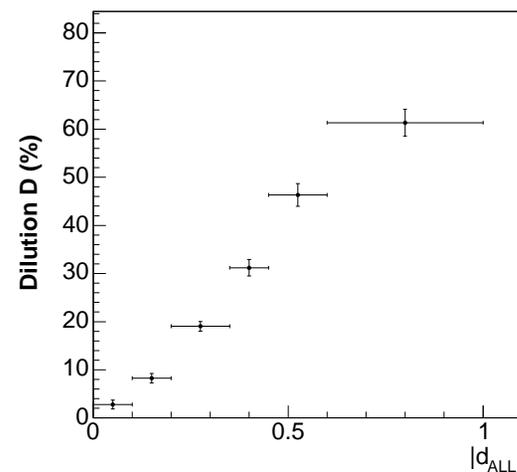
Wed Oct 31 22:54:17 2007



p20  $B_s \rightarrow \mu\phi\pi$  MC

PHPL.mct20\_alltag

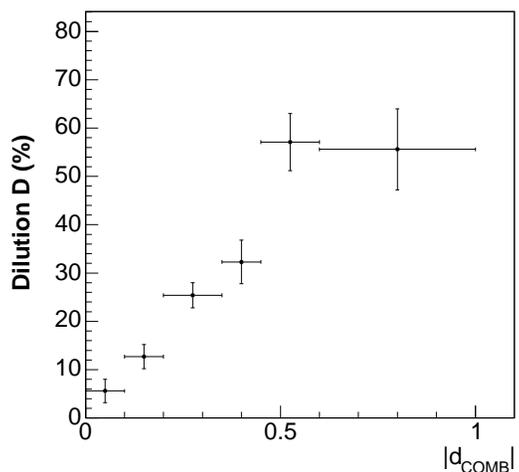
Thu Nov 1 01:05:42 2007



p17  $B_s \rightarrow J/\psi\phi$  MC

JPsiPHL.combSSTall

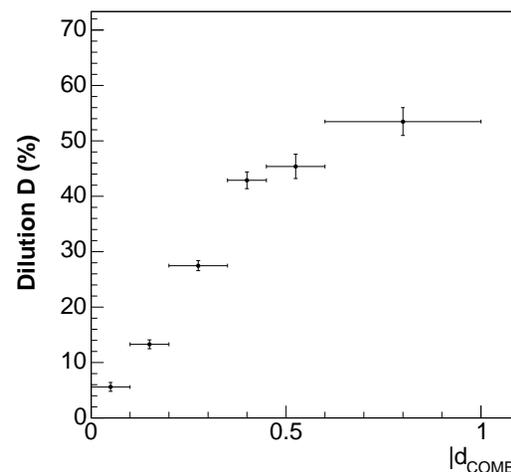
Thu Nov 1 01:06:59 2007



p17  $B \rightarrow J/\psi K$  MC

BJK.combSSTall

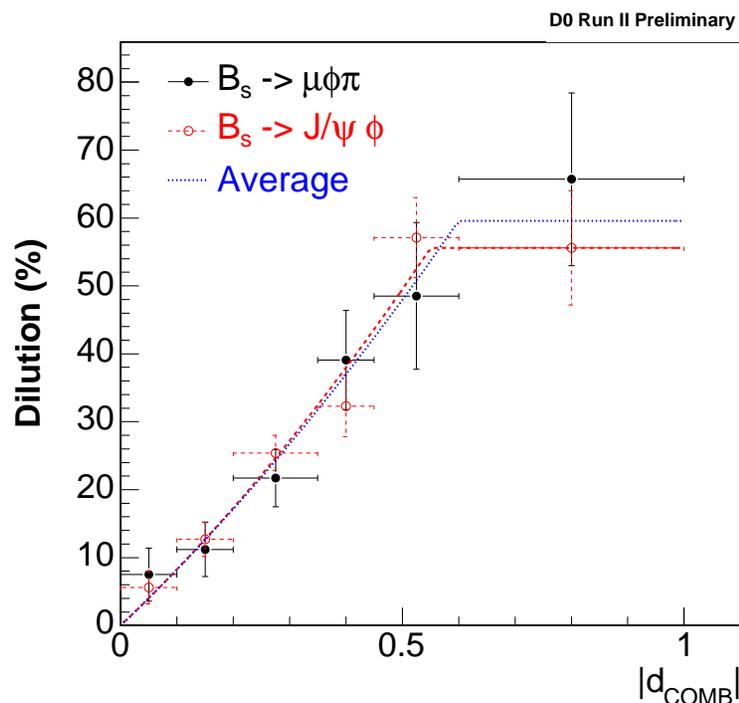
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# Calibration curves

To obtain calibration curve we fit two of the plots above:



- “Unbiased”  $\mu\phi\pi$  - fitted with straight line  $y = (89.50 \pm 12.27)x$
- $J/\psi\phi$  - fitted with parabola:  
 $y = (0.7834 \pm 0.2997)x + (0.4137 \pm 0.7446)x^2 \quad (x < 0.55)$   
 $y = 0.556 \quad (x > 0.55)$
- Average - fitted with parabola:  
 $y = (0.7895 \pm 0.3117)x + (0.3390 \pm 0.7616)x^2 \quad (x < 0.60)$   
 $y = 0.5957 \quad (x > 0.60)$



# Conclusion

- SST works for  $B_s \rightarrow \mu\phi\pi$  (p17 and p20 MC),  $B_s \rightarrow J/\psi\phi$  (p17 MC) and  $B \rightarrow J/\psi K$  (p17 MC)
- Combination of two SST algorithms (“Min.  $\Delta R$ ” and “ $Q_{jet}(p_t, \kappa = 0.6)$ ”) increases total  $\epsilon D^2$  compared to individual  $\epsilon D^2$ 's
- Combination SST + OST + EvtCh also increases total  $\epsilon D^2$  compared to individual  $\epsilon D^2$ 's
- Calibration curves are obtained and their parameters are given in the previous transparency